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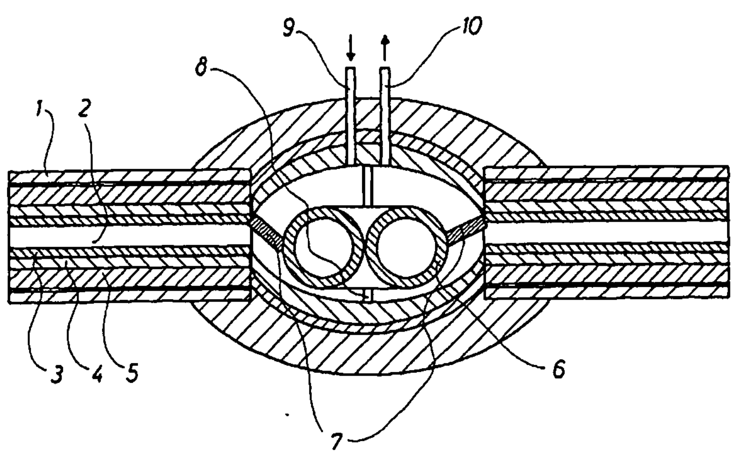
(54) Title: A NETWORK COMPRISING COMPENSATED POWER CABLE SECTIONS



(57) **Abstract:** An electrical power transmission network comprising a plurality of superconductive cable sections which are interconnected via connecting members. All cables have a certain inductance and a certain capacitance per length of unit. Therefore, a phase shift is introduced between current and voltage depending on the load, and this phase shift depends on the position along the cable. According to the invention, a phase compensation unit, e.g. a series inductance (6) or a universal power controller is arranged in each of the connecting members between the superconductive cable sections, said series inductance being e.g. cooled by means of the coolant which is used for the cooling of the superconductive cables. The invention further deals with an electrical power transmission network comprising a plurality of conventional cable sections, wherein the phase compensation unit comprises a superconducting coil or a universal power controller. Hereby, the phase compensation units along the cable may be made considerably smaller than known before and/or the compensation automated to dynamically keep the phase shift within a predetermined range.

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For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

A network comprising compensated power cable sections

The invention relates to an electrical energy transmission network comprising a plurality of superconductive cable sections, which are interconnected via connecting nodes.

The invention further relates to an electrical energy transmission network comprising a plurality of cable sections, which are interconnected via connecting nodes.

It relates more specifically to the compensation of phase differences between voltage and current in high-voltage cables for power distribution.

All power cables or freely hanging transmission lines have a certain inductance and a certain capacitance per length of unit. Therefore, a phase shift is introduced between current and voltage depending on the load, and this phase shift depends on the position along the cable.

It is known to introduce a plurality of series inductances along a line of superconductive cables, cf. e.g. B.M. Weedy and B.J. Cory, "Electric Power Systems", 4th Edition, Wiley, London, 1998, referred to as Weedy&Cory in the following. These series inductances serve to compensate for phase shifts along the line, which are caused by the circumstance that the individual cable has a certain capacity per length of unit. In the known structures, these series inductances must be incorporated in special housings which occupy relatively much space.

It is also known to introduce series inductances in particular on the ends of superconductive cables of the cold dielectric type, cf. e.g. WO 00/39811. Here, however, the purpose is to increase the own inductance of the cable to protect the cable in case of a short-circuit excess current.

The purpose of the present invention is to compensate the phase-shift between current and voltage along a power transmission cable, the phase shift being induced due to the construction, the power to be transmitted at a certain voltage and the load of the cable, to keep the phase-shift within a predetermined range, preferably less than 30 degrees.

A network for transmission of electrical energy according to the invention comprises superconducting cable sections and connecting nodes, said superconducting cable sections being mutually connected in said connecting nodes, wherein at least one and preferably all of said nodes comprise a phase compensation unit serially connecting two adjacent sections, said phase compensation unit being adapted to compensate the phase-shift between current and voltage that is introduced in one or more adjacent sections.

In the present context, the term 'superconducting cable section' is taken to mean a length of a superconducting cable that is used as a building block for the network in question, e.g. such a length that is produced with a view to the handling and layout and other practical issues in one piece without splicings of conductors. Such section lengths may be 500 m or 1 km or other

lengths complying with the above considerations. In other words, two superconducting cable sections may naturally be connected by a joint. A network according to the invention comprises at least two cable sections and one connecting node electrically connecting them.

In the present context, the term a 'connecting node' is taken to mean a joint or any other natural connecting point e.g. containing splicings between subsequent cable sections (either originally planned or established at a later point in time, e.g. after a cable damage or rupture).

It is anticipated that the superconducting cable sections are operated at temperatures below the critical temperature so that the critical current is sufficiently high to sustain virtually lossless electrical conduction.

An advantage of the invention is that the compensation is made at points of the cable where some sort of relatively easy access is often provided anyway (e.g. in an urban area), e.g. every km or so. An advantage of this is that a 'modular' system is provided increasing the flexibility and ease of maintenance of the system (leading to lower cost). By providing a compensation with relatively small intervals, each compensation remains relatively small and its physical implementation as well. A further advantage of such a 'distributed' compensation is that the cable system or network becomes more stable since each section of the network has its own compensation, thus lowering the damages in case of a cable injury. This is especially important in a network comprising superconducting

cables, because considerable damages can be incurred in case of a cable failure (over-currents leading to excess heating, etc.). Further, this strategy of compensation allows a practically unlimited size of the network (comprising a large number of superconducting cable sections). Finally, the compensation scheme according to the invention means that less charging current is needed, which results in a higher transmission capacity of the network.

By the term 'phase compensation unit' is understood any component or device that decreases the absolute magnitude of the phase angle between current and voltage when represented in a vector notation. Examples of a phase compensation unit may be an active or passive, fixed or variable impedance (comprising a resistance and a reactance), reactance (e.g. a combination of an inductance and a capacitance), inductance or capacitance.

In a preferred embodiment, the network further comprises one or more terminal nodes containing connections between a section of superconducting cable and terminating equipment, wherein at least one of said one or more terminal nodes comprise a phase compensation unit serially connecting said section of superconducting cable and said terminating equipment.

In the present context, the term 'terminating equipment' is taken to mean any equipment connected to the cable section, be it at a power plant substation, a transformer station, a user load, etc.

A compensation of the phase shift introduced in the cable section connected to the terminal equipment (and possibly in one or more of the preceding sections) may be conveniently performed in the terminal unit (easy to install and maintain). Further, the phase compensation unit may be combined with fault current limiting or diverting means and or means for impedance matching. At a

In a preferred embodiment, said phase compensation unit comprises a reactance, preferably an active reactance such as a universal power controller.

The term 'universal power controller' (UPC) is in the present context taken to mean a semiconductor high power, high voltage device that can inject a voltage in series with a line whose angle can have any desired relation with the phase voltage (see e.g. Weedy&Cory, p. 204). It may contain an energy storage device such as a battery, a capacitor or a superconducting inductance that stores energy for one cycle. An advantage of using an active reactance such as a UPC is that the compensation may be dynamically adjusted to ensure that the phase difference between current and voltage is kept within a certain predetermined range, e.g. +/- 30 degrees, preferably +/- 10 degrees, even in the face of varying loads of the network. The phase compensation unit, e.g. an active reactance, may alternatively be centrally controlled via a monitoring and control network, normally established parallel to the power distribution network.

In a preferred embodiment, said reactance comprises an inductance.

The inductance of a superconducting cable is in the order of 10 μH/km to 1 mH/km. Inductive compensations of the order of 0.1 Ω/km - 10 Ω/km may be relevant. For a given cable section and expected load, a predetermined average compensation may be determined and inserted as a fixed value or, preferably, adjustable according to the actual load.

In a preferred embodiment, said inductance comprises a superconducting coil.

An advantage thereof is that a superconducting coil constituting a given inductance may be made considerably smaller (of the order of a factor of 10) than a conventional coil. For comparison, a conventional Cu air coil (1.5 Ω, 400 A) has a volume of approximately 1 m^3 per phase, whereas an equivalent superconducting coil takes up approximately 0.1 m^3 per phase (exclusive of cooling means). Further, the generation of heat because of ohmic losses in the series inductance is avoided, which is especially advantageous in a cryogenic environment such a superconducting cable. A superconducting coil may advantageously be used for the same purpose in connection with a conventional power cable system, where the installations for compensating phase shifts typically have the size of buildings and represent a considerable system cost.

Examples on the design of superconducting coils are e.g. given in the article "Factors determining the magnetic field generated by a solenoid made with a superconductor having critical current anisotropy" by

Däumling, M. and Flukiger, R. in Cryogenics, Vol. 35, Issue.12, 1995, Page 867-870 and in the handbook "Superconducting Magnets" by Martin N. Wilson, Oxford University Press, Inc., January 1983 (ISBN: 0198548052).

In a preferred embodiment, said phase compensation unit is cooled to substantially the same temperature as the superconducting cable sections.

An advantage hereof is that transitions between cold and warm parts of the cable system are eliminated in the connecting nodes, thus saving coolant and reducing problems with iced over or wet parts due to condensation. The term 'substantially the same temperature is in the present context taken to mean within 10% of each other, preferably within 5%.

In a preferred embodiment, the phase compensation unit and one or both connected superconducting cable sections share the same coolant.

This has the advantage of simplification, potentially yielding a more stable system (by reducing the number of independent cooling systems). Some or all of the nodes containing the phase compensation units may be used as exit for used coolant and input of fresh coolant.

Alternatively, the node comprising the phase compensation unit may have a cooling system of its own, i.e. one which is independent of the cooling system of the superconducting cable sections.

In a preferred embodiment, the superconducting cable sections comprise more than one group of electrically conductive elements, each group being adapted for the distribution of one AC-phase and where a phase compensation unit for each group is inserted to serially connect corresponding groups in adjacent sections.

In a preferred embodiment, the superconducting coil is formed by a toroidal coil. This has the advantage of avoiding stray fields, which might otherwise degrade the superconductive properties and moreover be harmful to the environment.

In a preferred embodiment, a phase compensation unit is coupled to a superconductive cable section via an intermediate member of a material of low resistivity, e.g. copper. Alternatively, silver or an alloy of copper or silver may be used. An advantage of using these materials is, apart from their superior electrical conductivity, that it allows a relatively easy electrical connection of the phase compensation unit to the cable, e.g. by soldering.

In a preferred embodiment, the superconductive cable sections are formed as room temperature dielectric cable sections. In this embodiment, the network consists of superconducting cable sections for which the dielectric material is located outside the cryogenic system for maintaining the superconducting material below the critical temperature.

In a preferred embodiment, the superconductive cable sections are formed as cold dielectric cable sections.

In this embodiment, the network consists of superconducting cable sections for which the dielectric material is located inside the cryogenic system. A cold dielectric superconductive cable typically has a relatively low inductance per unit length.

In a preferred embodiment, the superconductive cable sections are formed as three-conductor cables sections. In this embodiment, the network consists of superconducting cable sections, which may be adapted to distribute power based on a 3 phase AC voltage.

The invention further relates to a network for transmission of electrical energy comprising cable sections and connecting nodes, said cable sections being mutually connected in said connecting nodes, wherein at least one and preferably all of said nodes comprise an inductance serially connecting two adjacent sections, said inductance being adapted to compensate the phase-shift between current and voltage that is introduced in one or more adjacent sections, said inductance being implemented as a superconducting coil.

An advantage thereof is that the volume of the installation for a given inductive compensation of a conventional cable may be considerably reduced, thereby reducing material costs and costs to buildings to house the installation.

In the present context, the term 'conventional cable' is taken to mean a non-superconducting cable comprising a substantial amount of electrical conductors having non-zero electrical resistance at a normal operating temperature of the cable.

The invention further relates to a network for transmission of electrical energy comprising cable sections and connecting nodes, said cable sections being mutually connected in said connecting nodes, wherein at least one and preferably all of said nodes comprise an active reactance such as a universal power controller serially connecting two adjacent sections, said active reactance being adapted to compensate the phase-shift between current and voltage that is introduced in one or more adjacent sections.

An advantage thereof is that the compensation may be dynamically adjusted to ensure that the phase difference between current and voltage is kept within a certain predetermined range, e.g. +/- 30 degrees, preferably +/- 10 degrees, even in the face of varying loads of the network. The active reactance may alternatively be centrally controlled via a monitoring and control network.

The object of *a second aspect of* the invention is to teach a) how such series inductances along a superconductive cable may be made considerably smaller than known before, b) to have the possibility of preventing a phase shift in the cable.

An electrical energy transmission network comprising a plurality of superconductive cables which are interconnected via connecting nodes, is characterized according to the invention in that a series inductance is arranged in each of the connecting nodes between the superconductive cables, said series inductance being cooled by means of the coolant which is used for the

cooling of the superconductive cables. Hereby, temperature differences between the cables and the series inductances are avoided, and thus it is not necessary to take special measures to ensure that heat is not emitted from the series inductances.

Further, according to *the second aspect of* the invention, the individual series inductance is formed by a superconductive coil. Hereby, generation of heat because of ohmic losses in the series inductance is avoided.

Moreover, according to *the second aspect of* the invention, the superconductive coil may be formed by a toroidal coil. This avoids stray fields, which might otherwise be destructive to the superconductive properties and might moreover be harmful to the environment.

Also, according to *the second aspect of* the invention, the inductance may be coupled to a superconductive cable via an intermediate member of a material of low resistivity, e.g. copper.

Also, according to *the second aspect of* the invention, the superconductive cables may be formed by room temperature dielectric cables.

Also, according to *the second aspect of* the invention, the superconductive cables may be formed by cold dielectric cables.

Also, according to *the second aspect of* the invention, the superconductive cables may be formed by three-conductor cables.

The invention will be explained more fully below with reference to the drawing, in which

fig. 1 shows a section through a connecting member for connecting two superconductive cable sections, said connecting member containing a series inductance,

fig. 2 shows a connecting member having a series inductance, a partition wall and connections to a cooling machine,

fig. 3 shows a connecting member in which the series phase compensation unit is [inductance is replaced by] an electrical circuit in the form of a universal power controller,

fig. 4 shows a detailed diagram of a universal power controller,

fig. 5 shows a room temperature dielectric superconducting cable,

fig. 6 shows a cold dielectric superconducting cable,

fig. 7 shows a network comprising superconducting cable sections and connecting nodes, and

fig. 8 shows a network comprising cable sections and connecting nodes.

In an electrical energy transmission network consisting of superconductive cables, series inductances may be introduced e.g. at regular intervals along the individual cable. Such series inductances may serve as power-limiting devices in the first place. The reason is that an inductance introduces an impedance of the value ωL, where ωπf and f = 50 Hz, and L is the inductance. The advantage of such an inductance is that it does not give rise to any energy loss, because the load is inductive. In case of excess current, the voltage drop across the inductance will thus limit the current. However, an inductance also causes a phase shift between current and voltage, and the size of the acceptable phase shift limits the size of the inductance, of course.

All power cables or freely hanging transmission lines have a certain inductance L and a certain capacitance C per length of unit. A phase shift is introduced between current and voltage depending on the load, which may be inductive or capacitive, and this phase shift depends on the length of the cable. Only in case of a so-called natural load impedance $Z_n = \sqrt{\frac{L}{C}}$ is no phase shift introduced. In most practical cases, this natural state of load cannot be achieved, however, e.g. because the load varies considerably during a day. In extreme cases the phase shift can even have as a result that it will not be possible at all to transmit energy along the line. Therefore, all transmission lines or cables require a periodic phase compensation along the individual line in order to be able to limit the phase shift caused by the transmission. Both inductive and

capacitive compensation may be involved, depending on the load, the voltage level and the cable characteristic.

If the terminating load impedance is larger than the natural load Z_n (corresponding to a power transfer of less than under natural load conditions), the capacitive effects will dominate, and therefore an inductive compensation must be used, and if the terminating load impedance is smaller than the natural load Z_n (corresponding to a power transfer of higher than under natural load conditions), the inductive effects will dominate, and therefore a capacitive compensation must be used. Today, most overhead lines are driven above the natural load and thus require a capacitive compensation, while underground cables, particularly in situations of low load, require an inductive compensation.

There are two types of superconductive cables, viz. room temperature dielectric cables and cold dielectric cables. The room temperature dielectric cable - see fig. 5 - consists of a former 20 through which coolants, e.g. liquid nitrogen, flow. A layer of superconductive tape 21 is wound around the former 20. A cryostat 22 in the form of an annular vacuum chamber is provided around the layer of superconductive tape 21, the distance between the inner and outer walls of the vacuum chamber being maintained by means of spacers. Externally on the cryostat 22 there is a layer of dielectric material 23, and externally on this layer a shield 24. The layer of dielectric material 23 substantially has room temperature.

The cold dielectric cable - see fig. 6 - consists of a former 31 through which coolants flow. A first layer of superconductive tape 32 is wound around the former 31. A layer of dielectric material 33 is provided around the first layer of superconductive tape 32. Around the layer of dielectric material 33 there is a second layer of superconductive tape 34. A cryostat 35 in the form of an annular vacuum chamber is provided around the last-mentioned layer of superconductive tape, the distance between the inner and outer walls being maintained by means of spacers. A shield 36 is provided externally on the cryostat 35. In this case, the dielectric material has a very low temperature.

In room temperature dielectric cables - see fig. 5 - the capacitance per length of unit is slightly higher, while the inductance per length of unit is comparable to the inductance of a standard power cable. The natural load is therefore the same or slightly smaller.

In cold dielectric cables - see fig. 6 - the capacitance per length of unit almost corresponds to the capacitance per length of unit in conventional cables, while the inductance per length of unit is slightly lower than in normal cables because of the additional superconductive layer that serves as a shield. The natural load impedance Z_n is thus significantly smaller than in conventional cables.

In addition to the load used, the compensation also depends on the voltage level in the cable and the maximum current, cf. e.g. the article "Power applications for superconducting cables", Inst. Phys.

Conf. Series No. 167, p. 1103 (1999) by O. Tønnesen et al. According to this article, the length of a superconductive cable is limited by the phase shift along the cable. It is therefore likely that superconductive cables require smaller series inductances than conventional cables. The connection of a series reactance e.g. in the form of a superconductive series reactance e.g. in the form of a toroidal coil will usually take place via an intermediate member 7 on both sides of the reactance. The individual intermediate member 7 is usually formed by a metal member of low resistivity, e.g. a piece of copper. This means that the superconductive cable will be connected, e.g. soldered, to a copper member, which is in turn connected, e.g. soldered, to a superconductive series reactance, which is in turn soldered via a copper member 7 to the superconductive cable on the other side.

In case of three-conductor cables, three series reactances have to be arranged in the connecting member.

Fig. 1 shows an example of a connecting member which connects two room temperature dielectric superconductive cables. 1 is a shield containing a copper mask and at any rate a water impermeable layer as well as optionally a further layer around a connection which is to be connected to the shield 1 on the other side. The copper shields of both electrical cables are hereby interconnected.

5 is an inner electrical insulation layer. This layer 5 may comprise a substrate which serves to ensure equal

distribution of the electrical field. The material of the layer 5 is typically the same in both cables, but need not be the same in the connecting member. The electrical insulation may be of the extruded type in the cable and of the wound type in the connecting member. A layer 4 below the layer 5 gives a thermal insulation. In practice, this thermal insulation is formed by a vacuum containing a multilayer insulation. Depending on the space which is available, this thermal insulation may be of another structure in the connecting member. The superconductor contained in the underlying layer 3 is connected by means of intermediate members 7 to a series reactance 6 (a toroidal coil) in the connecting member. A coolant, such as liquid nitrogen, flows through a cooling pipe 2 inside the superconductor layer 3. Alternatively, the superconductive layer 3 may be immersed in the coolant, in which case the inner wall of the thermal insulation 4 serves as an enclosure. The reactance 6 is cooled by means of the same coolant as the superconductor and must be formed in such a manner as allows it to be immersed in the coolant. Alternatively, cable-in-conductor conductors (CICC) may be used. Some connections 9, 10 for the supply of coolant from a cooling machine are shown in fig. 2.

In an alternative embodiment, the phase compensation unit consists of an electronic unit 11, which is driven at the temperature of the cable and may vary or compensate for changes in the phase angle. This electronic unit is referred to as a universal power controller 11 and is shown in fig. 3 for a room temperature dielectric cable. It may also be used in connection with a cold dielectric cable. The universal

power controller 11 is shown in greater detail in fig. 4 and will be explained more fully below.

The development of controlled high-voltage semiconductor devices has produced inverters which can inject a voltage in series with a line voltage, whose angle may have any desired relation to the phase voltage. This is equivalent to introducing a capacitor in series, except that the voltage is not limited to being 90° phase-shifted relative to the current. Such a device is referred to as a universal power controller and is shown in fig. 4 together with a phase diagram to illustrate the mode of operation. It will be seen that if the injected voltage is 90° phase-shifted relative to the current, then no energy is tapped from the source of energy. At any other angle, energy is tapped either from the source or other parts of the system. The source of energy may e.g. be formed by a transformer which is connected to system bus bars, which feed a rectifier that provides a signal, of which a sine-shaped injection voltage of the desired amplitude and angle is synthesized. Alternatively, the source of energy may be a storage device, such as a battery, a capacitor or a superconductive energy storage, in which case an auxiliary charge may be necessary. The superconductor can carry great current densities, e.g. 10-100 times the current density of copper. According to the invention, the necessary volume of the series reactances may be reduced considerably, however, thereby avoiding large extra structures and allowing the reactances to be housed in the connecting member.

Fig. 7 shows a network 70 according to the invention comprising superconducting cable sections 72 and connecting nodes 73.

The network comprises terminal nodes 74, where the superconducting cable sections (conductors and cryostates, etc.) are terminated and connected to terminal equipment at room temperature (e.g. sub-stations connected to an electrical power plant source or to a user load) or to conversion equipment (e.g. transformers at a transformer station) for converting the transmitted voltage to another level for further distribution. The superconducting cable sections 72 may be implemented as warm dielectric sections, where the main dielectric material is positioned outside the cryostate for cooling the superconducting material (cf. fig. 5) or cold dielectric sections, where it is positioned inside (cf. fig. 6). The signature 75 indicates that a multitude of sections 72 may be serially connected. The connecting nodes 73 comprising a phase compensation unit serially connecting adjacent cable sections 72 may be implemented as a dividing box to allow cable sections to be branched (not shown).

As an example a network comprising sections of superconducting cable with a rating 132kV, 1kA (230MVA) of e.g. length 1 km, having a capacitance of about 2.5 10^{-7} F/km and an inductance of 10^{-3} H/km is taken. This leads to a charging current (due to the cable capacitance) of about 10 A/km (50 Hz operation), corresponding to a reactive power generation of about 2 MVAr/km. This charging current is reactive, and thus for an uncompensated cable length of 100 km is equal to the rating of the cable. No power could be transmitted,

though, as the current is reactive. The critical angle of 30 degrees is reached at a cable length of 50 km, if the cable is fully loaded with a real component of the current of 866 A. For a smaller load the angle becomes larger because the charging current depends only on the cable voltage and not its load. An inductive compensation of the order of 1.1 Ω/km is appropriate in this case at full load, and more at smaller load. Examples for other voltage levels can be found in any text book on electric power systems, for example the one by Weedy&Cory (p. 196).

Fig. 8 shows a network 80 according to the invention comprising cable sections 82 and connecting nodes 83.

The network comprises terminal nodes 84, where the conventional cable sections are terminated and connected to terminal equipment sub-stations, transformer stations or user loads or to conversion equipment for adapting impedances etc. to another transmission medium (superconducting cable sections, overhead line sections, etc.). The signature 85 indicates that a multitude of cable sections 82 may be serially connected. The connecting nodes 83 are joints comprising a superconducting coil with its own cooling system, the coil serially connecting adjacent cable sections and compensating the phase difference 'induced' in a preceding section. A network comprises at least two sections 82 connected by a node.

The networks depicted in figs. 7 and 8 may be configured as a linear network (source-load), a loop or a grid. In a preferred embodiment the networks of figs. 7 and 8 are combined via a terminal node (the node

dealing with impedance differences, termination of cryostate systems, protection systems, etc), so that the network comprises conventional cable sections with superconducting coils in the joints between the conventional cable sections and superconducting cable sections with phase compensations units, e.g. in the form of UPCs or superconducting coils, in each joint between superconducting cable sections. If convenient, the phase compensation in the joints 83 between conventional cable sections may alternatively be provided also by UPCs.

The same principles may be used in part in connection with terminals.

PATENT CLAIMS

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1. A network for transmission of electrical energy comprising superconducting cable sections and connecting nodes, said superconducting cable sections being mutually connected in said connecting nodes, wherein at least one and preferably all of said nodes comprise a phase compensation unit serially connecting two adjacent sections, said phase compensation unit being adapted to compensate the phase-shift between current and voltage that is introduced in one or more adjacent sections.

2. A network according claim 1, said network further comprising one or more terminal nodes containing connections between a section of superconducting cable and terminating equipment, wherein at least one of said one or more terminal nodes comprise a phase compensation unit serially connecting said section of superconducting cable and said terminating equipment.

3. A network according to claim 1 or 2, wherein said phase compensation unit comprises a reactance, preferably an active reactance such as a universal power controller.

4. A network according to claim 3, wherein said reactance comprises an inductance.

5. A network according to claim 4, wherein said inductance comprises a superconducting coil.

6. A network according to any of the preceding claims, wherein said phase compensation unit is cooled to substantially the same temperature as the superconducting cable sections.

7. A network according to claim 6, wherein the phase compensation unit and one or both connected superconducting cable sections share the same coolant.

8. A network according to any of the preceding claims, wherein the superconducting cable sections comprise more than one group of electrically conducting elements, each group being adapted for the distribution of one AC-phase and where a phase compensation unit for each group is inserted to serially connect corresponding groups in adjacent sections.

9. A network according to claim 5, wherein the superconducting coil is formed by a toroidal coil.

10. A network according to any of the preceding claims, wherein a phase compensation unit is coupled to a superconductive cable section via an intermediate member of a material of low resistivity, e.g. copper.

11. A network according to any of the preceding claims, wherein the superconductive cable sections are formed as room temperature dielectric cable section.

12. A network according to any one of claims 1-10, wherein the superconductive cable sections are formed as cold dielectric cable sections.

13. A network according to one of the preceding claims, wherein the superconductive cable sections are formed as three-conductor cable sections.

14. A network for transmission of electrical energy comprising cable sections and connecting nodes, said cable sections being mutually connected in said connecting nodes, wherein at least one and preferably all of said nodes comprise an inductance serially connecting two adjacent sections, said inductance being adapted to compensate the phase-shift between current and voltage that is introduced in one or more adjacent sections, said inductance being implemented as a superconducting coil.

15. A network for transmission of electrical energy comprising cable sections and connecting nodes, said cable sections being mutually connected in said connecting nodes, wherein at least one and preferably all of said nodes comprise an active reactance such as a universal power controller serially connecting two adjacent sections, said active reactance being adapted to compensate the phase-shift between current and voltage that is introduced in one or more adjacent sections.

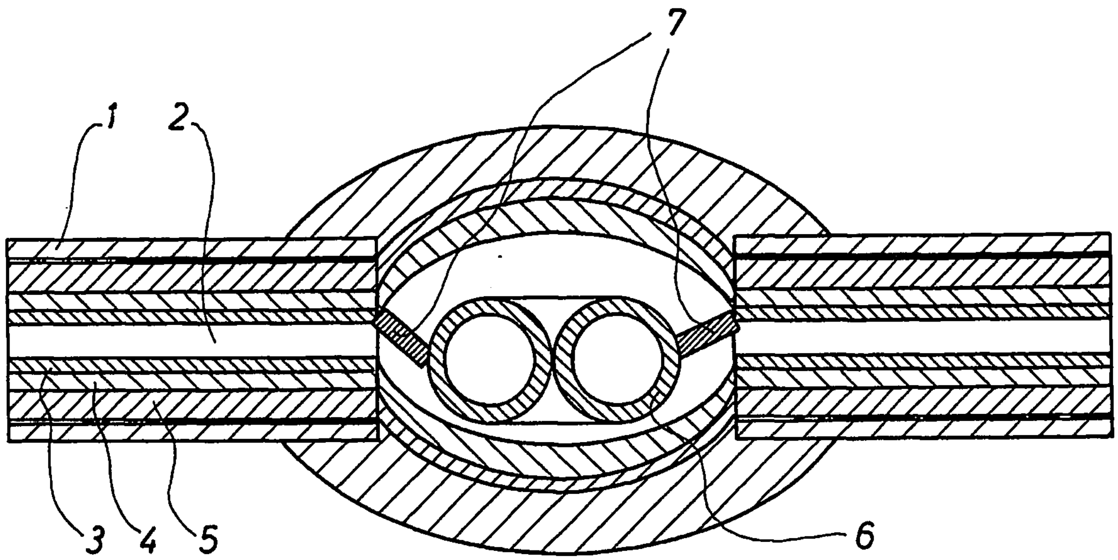

Fig. 1

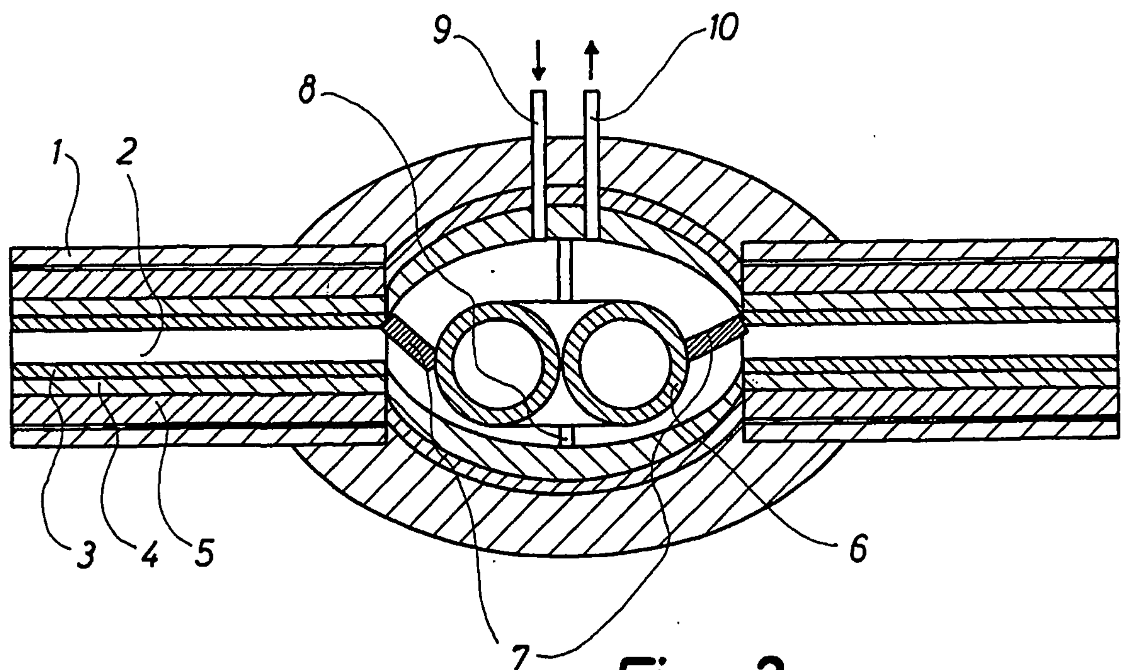

Fig. 2

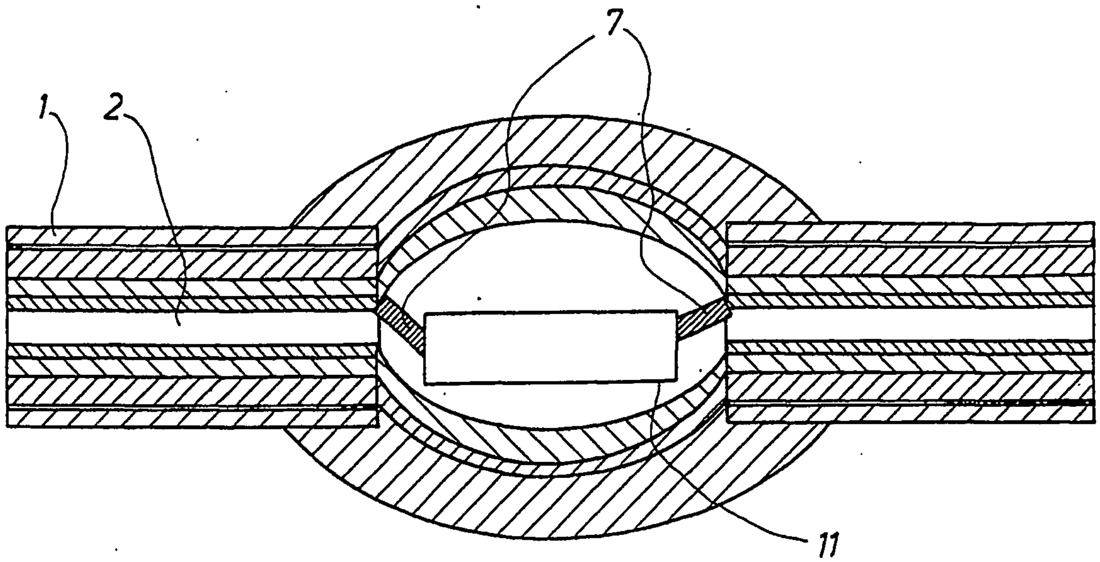
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Fig. 3

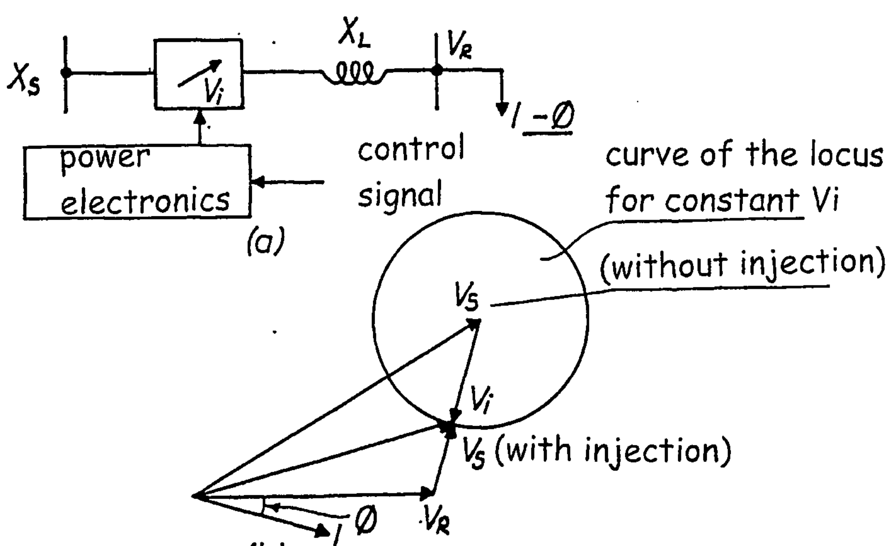
X_S
V_i
X_L
V_R
$I \underline{-\emptyset}$
power electronics
control signal
(a)
curve of the locus for constant Vi
(without injection)
V_S
V_i
V_S (with injection)
$\emptyset$
V_R
I
(b)

Fig. 4

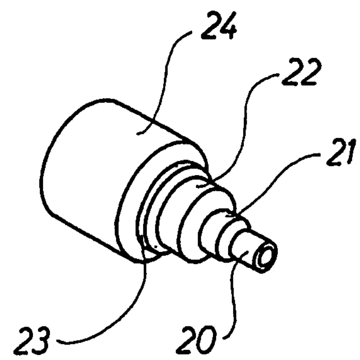

Fig. 5

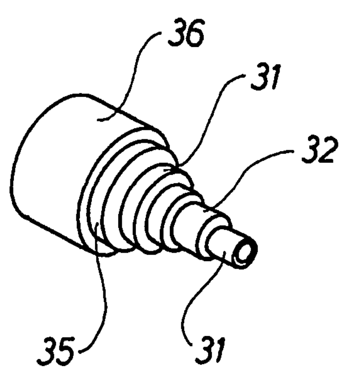

Fig. 6

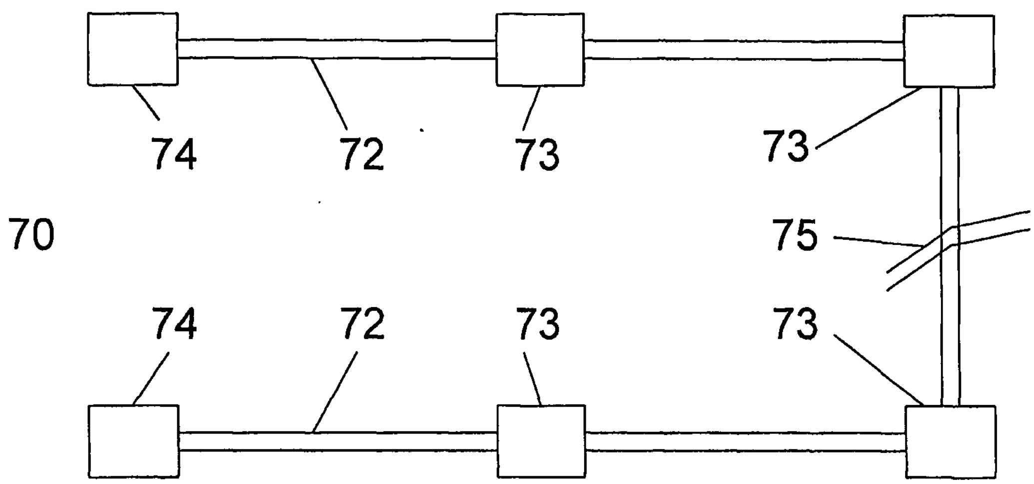

Fig. 7

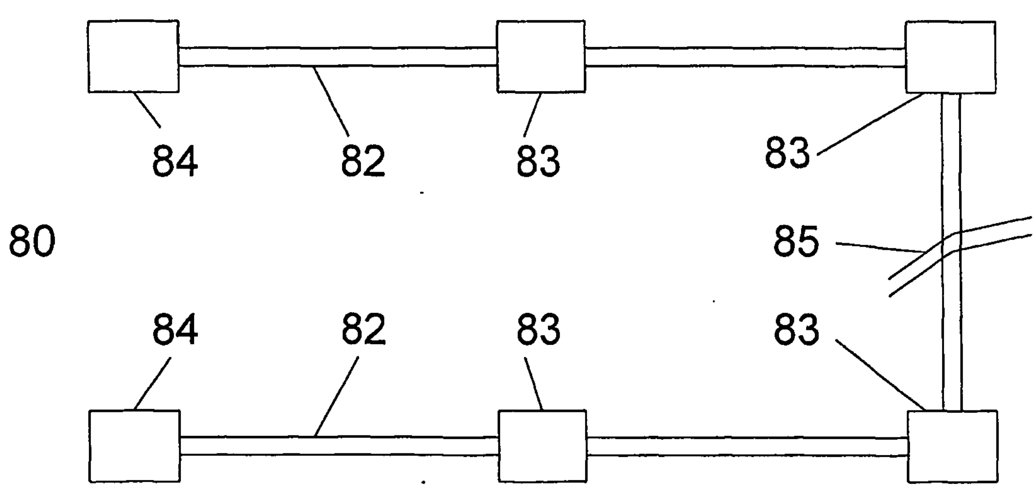

Fig. 8

INTERNATIONAL SEARCH REPORT

International Application No
PCT/DK 02/00159

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H02J3/22 //H01B12/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H02J H01B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 00 39811 A (NASSI MARCO ;LADIE PIERLUIGI (IT); PIRELLI CAVI E SISTEMI SPA (IT)) 6 July 2000 (2000-07-06) page 7, line 10 - line 24 page 20, line 14 - line 22 abstract ---	1-13
X	WO 00 39816 A (FROMM UDO ;HOLMBERG PAER (SE); ABB AB (SE); SASSE CHRISTIAN (SE);) 6 July 2000 (2000-07-06) abstract ---	14
X	WEEDY ET AL : "Electric power systems." 1998 , JOHN WILEY &SONS LTD ., ENGLAND FOURTH EDITION XP002902478 ISBN: 0-471-97677-6 page 204 -page 205 --- -/--	15

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

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Date of the actual completion of the international search	Date of mailing of the international search report
23 May 2002	
Name and mailing address of the ISA	**Authorized officer**
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Tomas Erlandsson

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INTERNATIONAL SEARCH REPORT

International Application No
PCT/DK 02/00159

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP 0 780 926 A (PIRELLI CAVI SPA) 25 June 1997 (1997-06-25) abstract -----	1-13

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INTERNATIONAL SEARCH REPORT

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International Application No
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